



Fluids and Combustion Facility Preliminary Design Review



FCF Combustion Requirements Compliance for Basis Experiments (SRED) and *Real Experiments*

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February 15, 2001



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Summary Compliance Summary for Combustion Basis Experiments and **Real Experiments**

BASIS EXPERIMENTS	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11
Comply											

Science Requirements Envelop Document (SRED)

Appendix B and F

REAL EXPERIMENTS				FIST		DCE-II		SEDC	Cool Flame	SIBAL	TIGER-3I
Accommodate											

Real Experiments are in various stages of development

 Comply

 Caution



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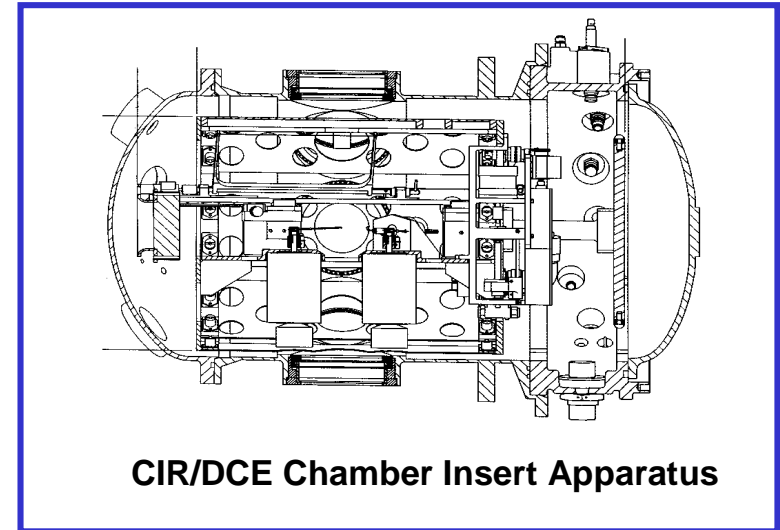
Droplet Combustion Experiment (c6) – DCE II

Real Experiment Science Summary

- PI: Williams of UC San Diego
- PS: Nayagam-NCMR@ GRC

Experiment Summary

- Single, liquid methanol/water droplets burn in quiescent O₂/N₂/He environments, freely deployed and with fiber support
- Droplet size, flame location, flame radiation are measured
- Burning rate constants, flame to droplet diameter ratios, key burning zone species concentrations, droplet extinction diameter, and broad band and water band radiation variations are found



Key CIR - Experiment Interface Requirements

- Chamber Insert Apparatus provides fuel, igniter assembly, droplet growth and deployment system, color camera and radiometers
- Atmosphere is .5 to 3 atm with O₂/N₂/He mixtures provided by the FOMA. Cleanup is every 4 test points and before venting
- Diagnostics provided by CIR:
 - Flame images of OH and CH
 - Back lit droplet images at high frame rate and high resolution
- Color images of droplet operations and ignition provided by MDCA
- Acceleration environment .6 to 60 x 10⁻⁵ g/go provided by ARIS



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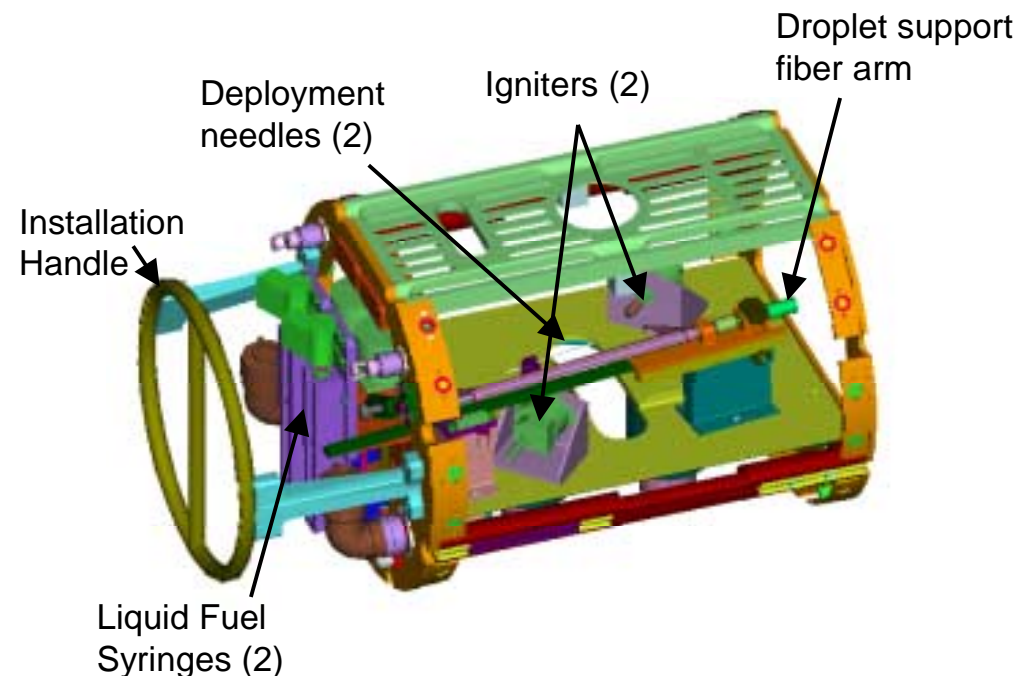


Droplet Combustion Experiment (c6) – DCE II

- Continuation of DCE which flew on the Microgravity Science Lab in 1997
- MSL configuration: 6 Middeck Locker Equivalent + stowage
- DCE
 - Heptane in O₂- He atmosphere
 - 35mm Film@80 fps & UV intensified (OH) on video
- DCE-2
 - Methanol/Water in O₂- He-N₂ atm
 - Digital imaging & UV intensified (OH, CH) on video



Droplet Image from MSL



DCE 2 Chamber Insert Assembly



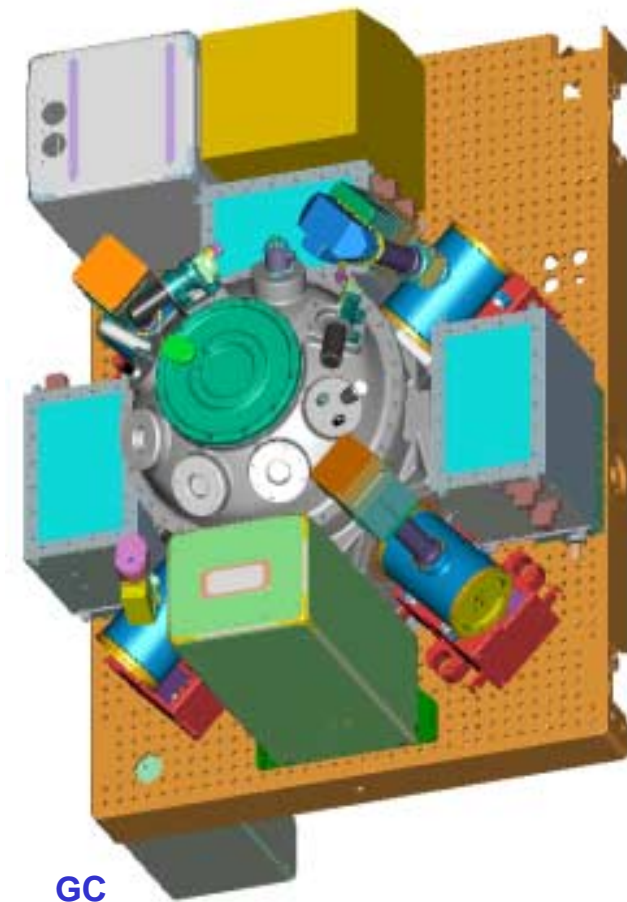
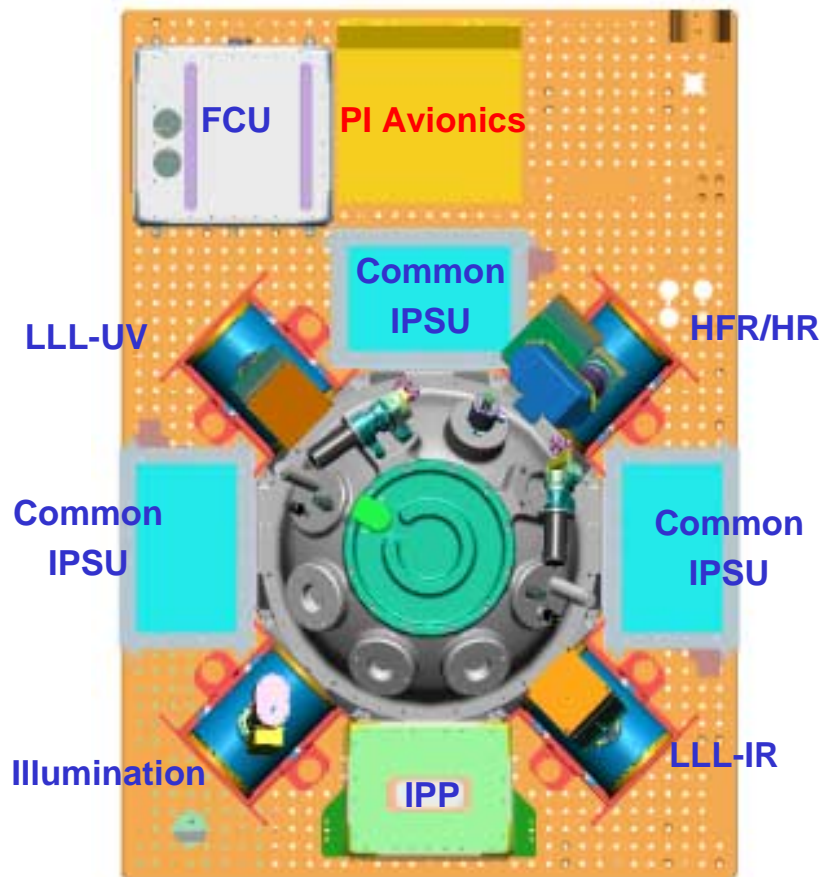
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Droplet Combustion Experiment (c6) – DCE II

Proposed Experiment Layout in CIR





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Summary of CIR/DCE II Compliance With DCE II SRD/Derived Requirements

System	Key Requirement	CIR H/W	DCE H/W	Other	Compliance
Test Chamber	insert size: 62.7cm long x 36.9 cm dia 18 to 29C test environment .25 to 3 atm initial pressure	Chamber " "	insert	Water loop	comply " "
Test Gas Conditions	O2 mole fraction 1% +/- 0005 of desired water vapor <2% O2 levels to 40 % He levels to 40%, rest N2	FOMA/ gas bottles FOMA filter FOMA/ gas bottles FOMA/ gas bottles	initial bottle gas mixtures initial bottle gas mixtures initial bottle gas mixtures		" " " "
Acceleration Environment	need levels ~10 ⁻⁵ g need measurement accuracy 10 ⁻⁶ g need freq measurement 0-125 Hz			ARIS SAMS FF SAMS FF	" " "
Minimum # Test Pts	80 pts in 4 months	CIR ops	DCE Ops	ISS Crew time/down k	"
Droplet Imager	80 fps at 1cm fov, 20 um resolution 80 fps at 3 cm fov, 60 um resolution 3 cm depth of field	HFR/HR HiBMs either camera			" " "
Secondary Imager	30 fps 4 cm fov 4 cm dof std video resolution		Color Camera " " "		" " " "
CH & OH Imagers (2)	431 & 310 nm bandpass filters 30 fps 90 um resolution 5 cm fov 4 cm dof colinear views for cameras	LLL (2) & OH filter " " " " bench configuration	CH filter		" " " " "
Data Requirements	all data time synched to .03 sec	IOP			"
Avionics	space for control & ops of CIA devices	Optics bench	avionics box		physical space need

Summary: DCE II interface requirements with CIR are capable of being met by the CIR design.



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Droplet Combustion Experiment (c6) – DCE II

Critical Hardware Summary

FCF Provided	PI Provided
<ul style="list-style-type: none">• HFR/HR * or HiBMs w/50mm FOV Relay *• LLL-UV w/ 42mm FOV objective & 310nm filter *• LLL-IR w/45-90mm objective *• Illumination• 3 Common IPSUs *• 1 IPP *• 4 Sapphire Windows & 4 Blanks• Pressure Measurements• SAMS• FCU *• 1-3" Adsorber Cartridge• 1-1L 50% and 3-2.25L 50% O2Bottles• 1-1L 100% Helium• 1,204 liters ISS N2• Chamber temperature measurements• Atmospheric Mixing & Delivery	<ul style="list-style-type: none">• PI Avionics Box *• CIA<ul style="list-style-type: none">– Radiometer– Ignition System– Color Camera– Liquid Fuel & Dispensing Mech.

* Includes embedded software



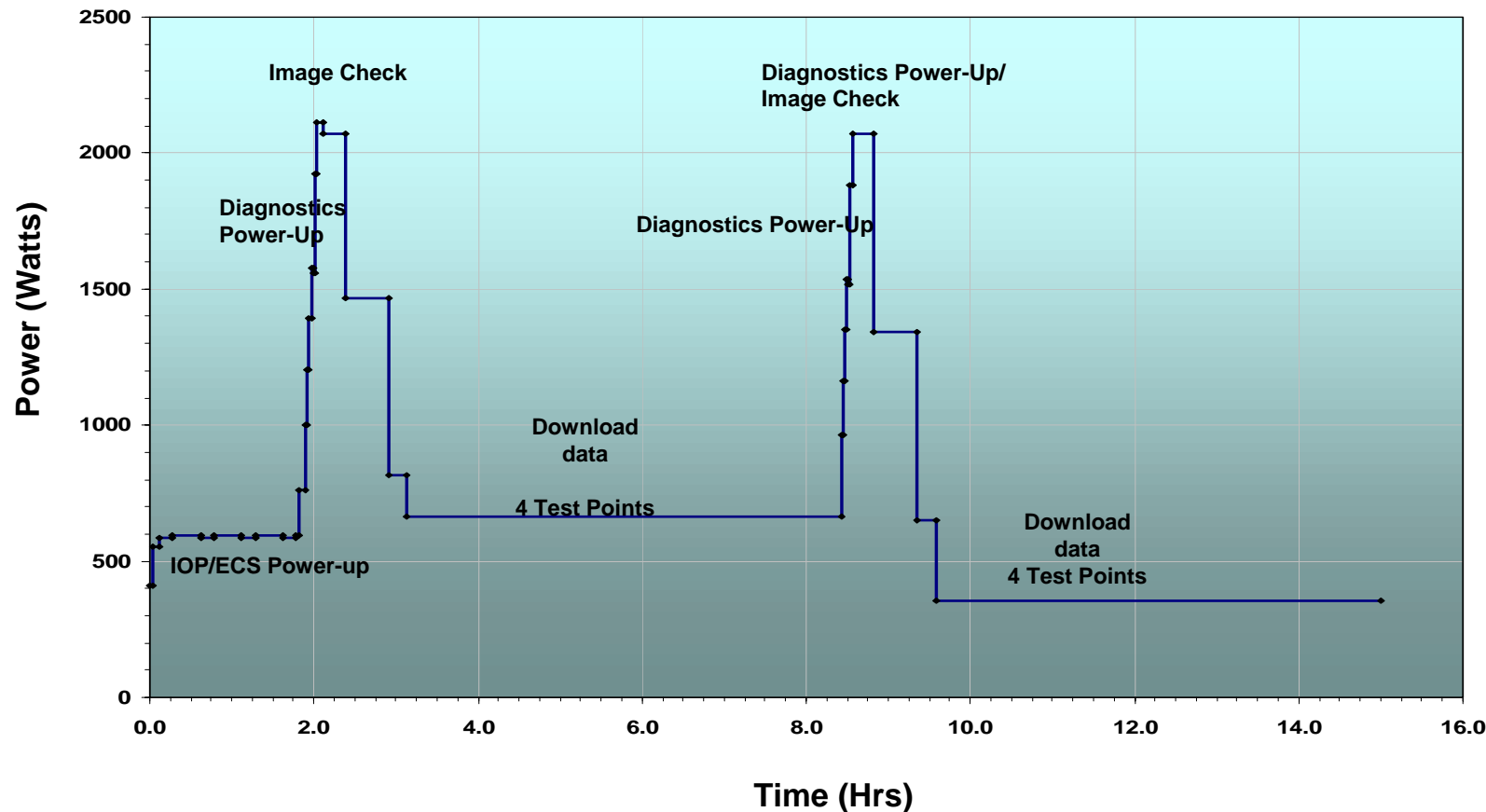
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Droplet Combustion Experiment (c6) – DCE II

Operation Power Profile



Represents worst case profile

Assumptions:

- 1354.7 GB data generated by experiment (3.81 GB per test point)
- 364 test points per experiment (60 seconds data recording per test point)
- Downlink data rate from IOP to TSC of 0.596 MB/s.
- Data downlink provided after 4 test points, clean after 4 successive test points
- **PI Avionics Power 75 W, PI CIA Power 260 W**

Peak Power = 2055.4 W
PI Peak = 1213 W
Facility Peak = 756 W
Peak Duration = 5 min.
Average Power = 698 W
Total Energy = 476.7 kW-h



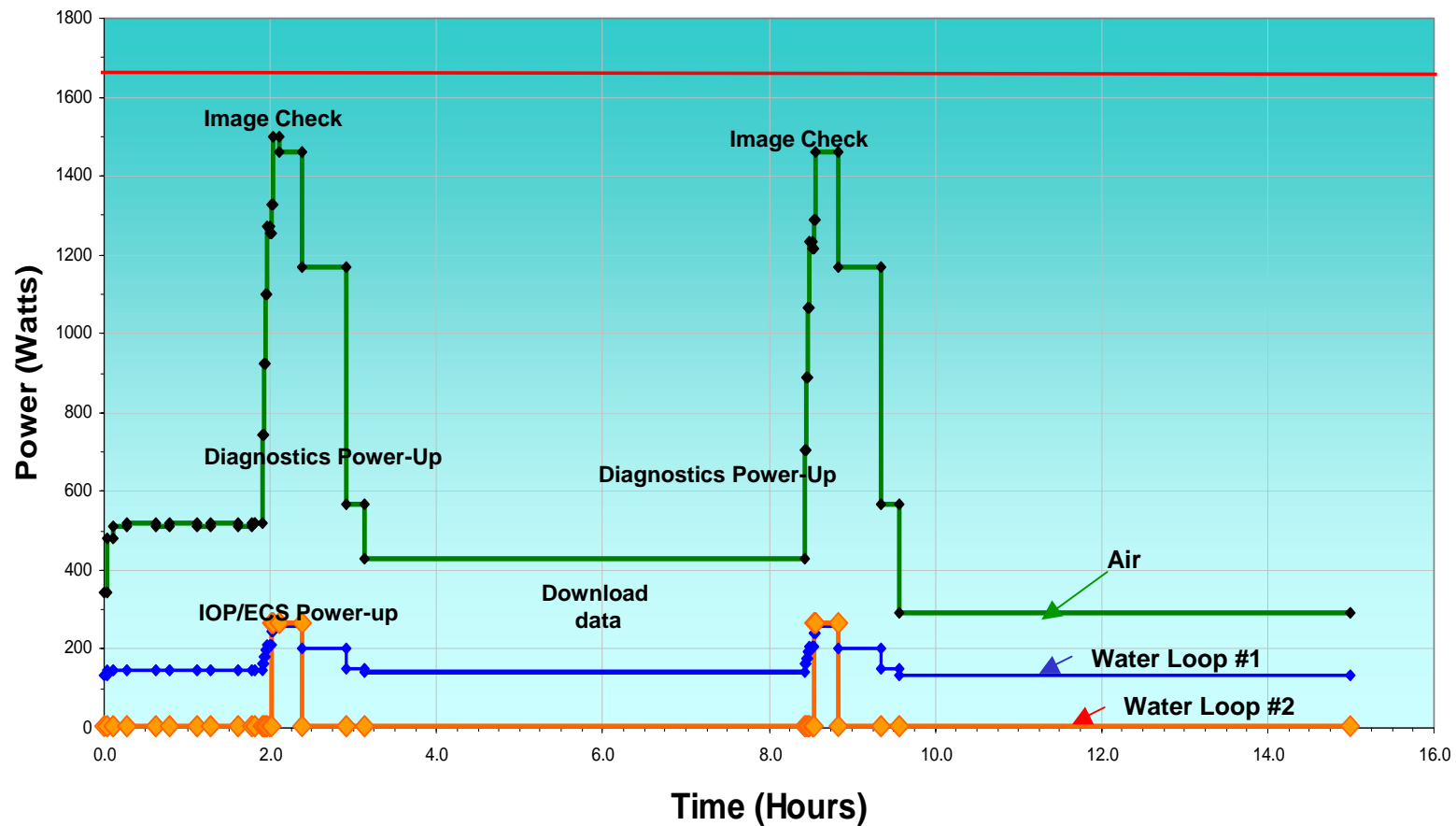
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Droplet Combustion Experiment (c6) – DCE II

ECS Load Profile



Peak ATCU Load = 1498.7 W

Peak WTCS Load = 532 W



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Droplet Combustion Experiment (c6) – DCE II

Mass and Stowage Estimates

	Operating Base Mass [kg]		Up Mass [kg]	Stowage Volume [m ³]
c6	1021.50	Total PI Provided	107.89	0.1849
		CIA	45.70	0.0941
		PI Avionics	19.80	0.0220
		2 - 1.0 L Bottle	8.00	0.0080
		3 - 2.25 L Bottles	20.13	0.0180
		2 Spare Deployment Needles Assembly	0.08	0.0003
		1- Igniter Tip Assembly	0.0006	0.000002
		11 Fuel Reservoirs	8.50	0.0114
		1 Retractable Indexing Fiber	0.98	0.0308
		1 Adsorber Filter	4.7	0.0002325



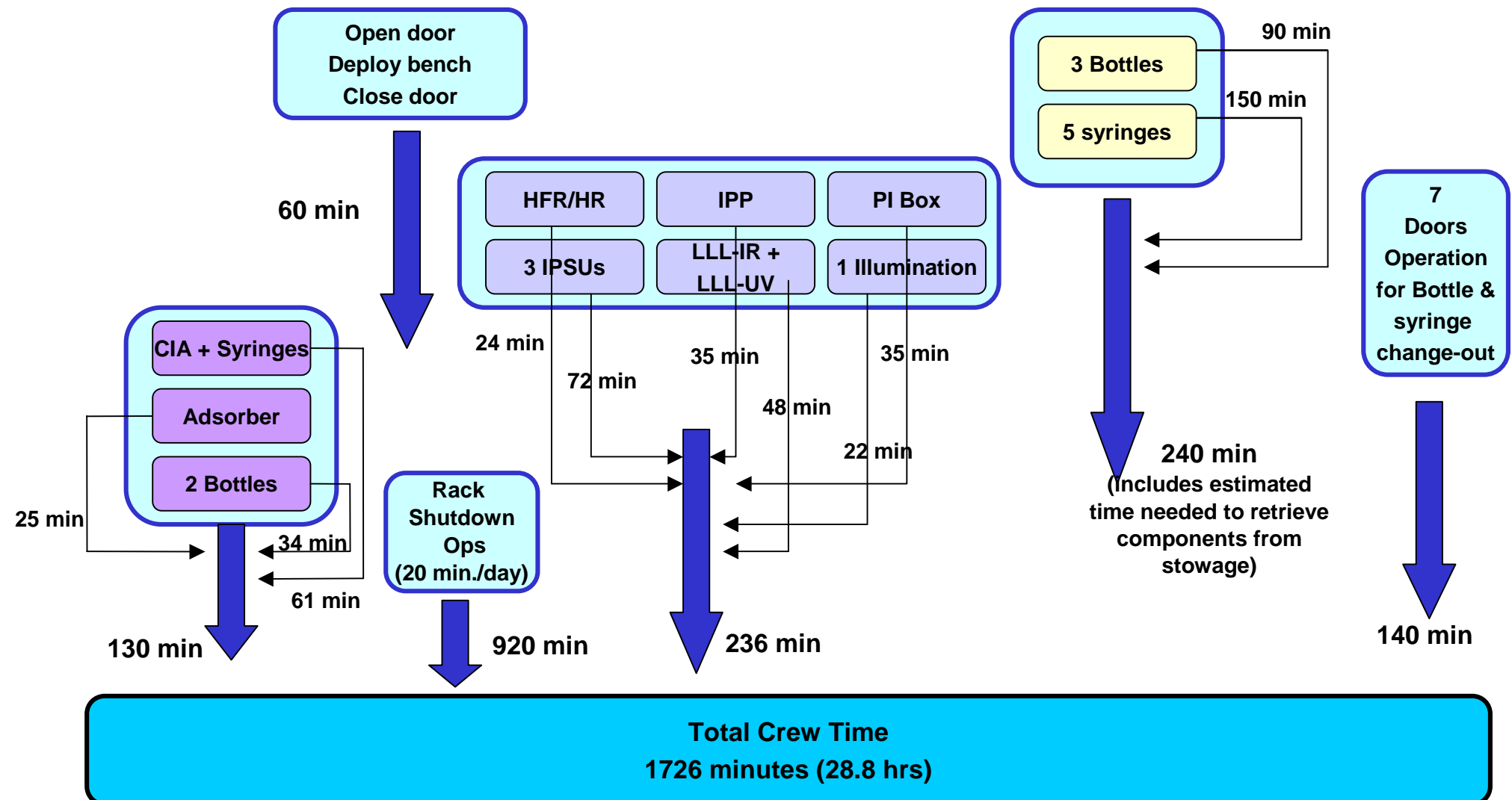
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Droplet Combustion Experiment (c6) – DCE II

Experiment Crew Time Estimates





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Droplet Combustion Experiment (c6) – DCE II

Summary

- A total of 364 test points
 - 160 test points for set # 1
 - 60 test points for set # 2
 - 144 test points for set # 3
- CIA contains color camera with signal routed to Common IPSU via MDCA Avionics
- ECS loads within CIR capability
- Experiment requirements are within the Facility resource allocations
 - Data: 1354.7 GB
 - Power: 698 Watts (average); 2055 Watts (peak)
 - Energy: 476.7 kW-h
 - Mass: 1021.5 kg
 - Crew Time: 28.8 hrs (includes rack shutdown with ARIS lockdown procedure)
 - Total Experiment Operational Run Time for 364 test points: 46 days

FCF (CIR + PI Hardware) complies with all requirements



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Turbulent Gas Jet Diffusion Flames (c1)

Real Experiment Science Summary

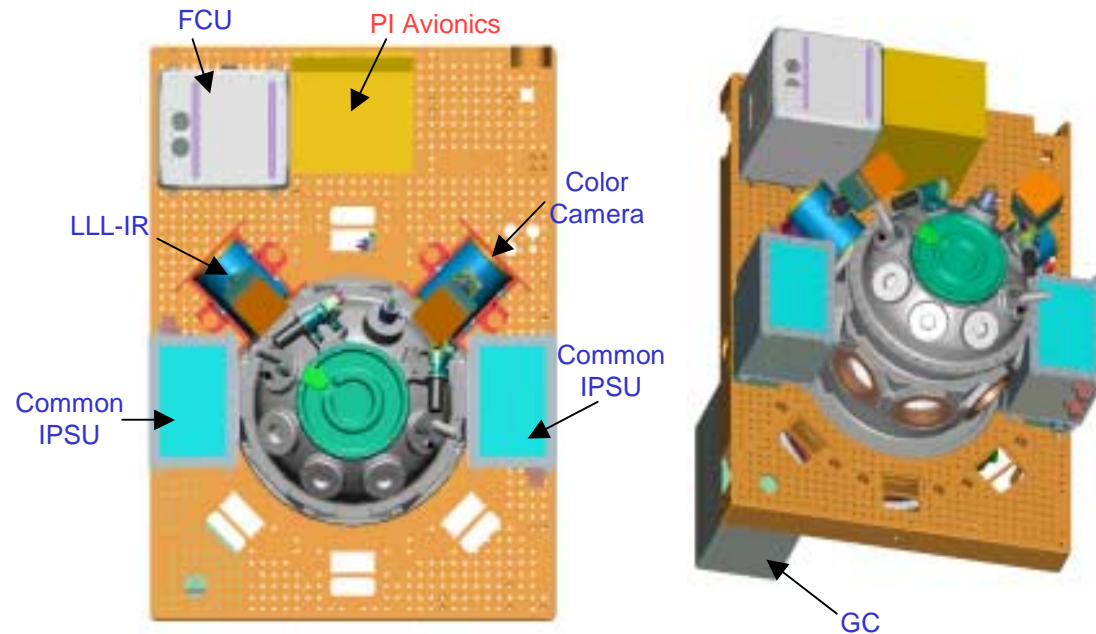
- PI: Bahadori
- PS: Stocker, GRC

Experiment Summary

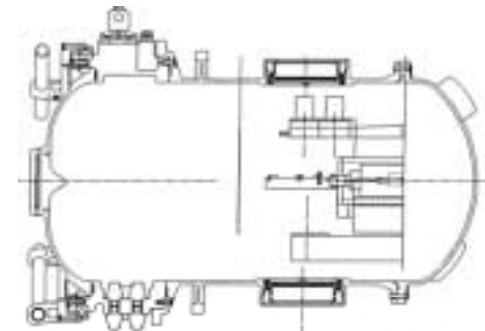
- Propane gas jet diffusion flames burn that are physically disturbed near the base of the flame
- Flame size and flame location in response to imposed disturbances are measured

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, igniter assembly, temperature point measurement devices and flame disturbance mechanism
- Atmosphere is 1 atm with O₂/N₂ mixtures provided by the FOMA. O₂ concentration 22%.
- Diagnostics provided by CIR:
 - Two orthogonal views of the flame. One color
 - Chemical composition of the burned gas samples
- Acceleration environment range 10⁻³ to 10⁻⁵ g/go provided by ARIS



Diagnostics Layout in CIR



CIR/TGDF Chamber Insert Apparatus



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Summary of CIR/TGDF Compliance With TGDF SRD/Derived Requirements

System	Key Requirement	CIR H/W	TGDF H/W	Other	Compliance
Test Chamber	Insert size: 28.7cm long x 34.2 cm dia interior wall emissivity >.9 over visable initial press 1 atm, final to 2.5 atm @ 48 l.	Chamber Test chamber "	insert		comply " "
Test Gas Conditions	O2 mole fract acc .3% of desired O2 mole fraction 22% N2 mole fraction 78% post burn analysis: CO,CO2,O2 propane to 5%; NO,NO2, N2 to 10%	FOMA gas bottles FOMA gas bottles FOMAgas bottles Gas Chromo. Gas Chromo.	intial bottle gas mixtures intial bottle gas mixtures intial bottle gas mixtures		" " " " "
gaseous fuel flow	flow rate of 1.86 + .04 cc/s				"
Acceleration Environment	need levels ~10-4 go need freq mesurement 0-15 Hz			ARIS SAMS FF	" "
Minimum # Test Pts	32 pts	CIR ops	TGDF Ops	ISS Crew time/downlk	"
Test Duration Estimate	500 sec	Test chamber			"
flame disturbance imaging	30 fps 18 x 8 cm fov 5 cm dof resolution: 500 - 1000 um	Color Cam " " "			" " " "
low light level imaging	30 fps 18 x 8 cm fov 5 cm dof resolution: 500 - 1000 um orthogonal view to color camera	HiBMS " " " "		CIA arrangement	" " " " "

Summary: TGDF interface requirements with CIR are capable of being met by the CIR design.



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Structure of Flame Balls at Low Lewis #s (c2)

Real Experiment Science Summary

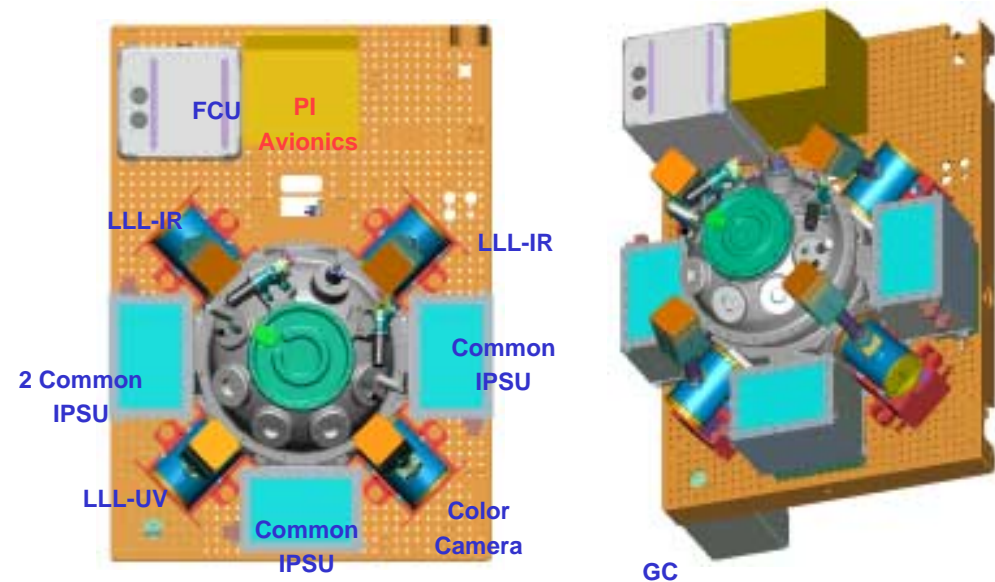
- PI: Ronney, USC
- PS: Weiland, GRC

Experiment Summary

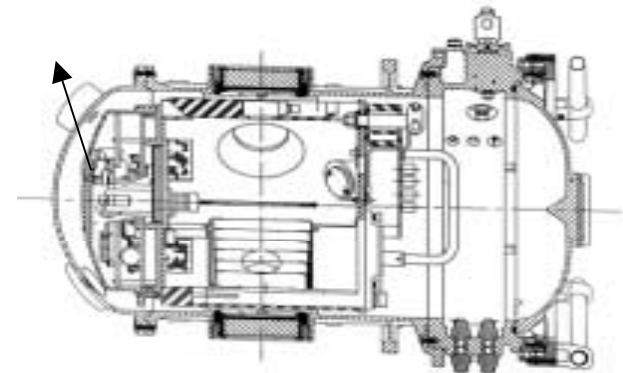
- Study flame balls that exist in a spark ignited, premixed quiescent environment
- Flame shape, size and structure, length of burn time, temperature, flame radiation and amount of fuel and O₂ consumed are found

Key CIR - Experiment Interface Requirements

- Chamber insert provides ignition mechanism, radiometric detection and point temperature measurements
- Fuel/oxidizer/diluent mixtures provided by FOMA
- Operating pressure is 1 or 3 atm
- Diagnostics provided by CIR:
 - Three flame views: One provides long pass wavelength detection orthogonal to OH imaging. Third view is color.
 - Species composition via GC
- Acceleration environment range 10⁻⁵ to 0.05 g/go is provided by ARIS



Diagnostics Layout in CIR



CIR/SOFBALL Chamber Insert Apparatus 15



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Summary of CIR/SOFBALL Compliance With SOFBALL SRD/Derived Requirements

System	Key Requirement	CIR H/W	Sofball H/W	Other	Compliance
Test Chamber	Insert size: 62.2 cm long x 39.6 cm dia interior wall emissivity >.9 over visible initial press 1-3 atm, accuracy 3% of reading	Chamber Test chamber "	insert		comply " "
Test Gas Conditions	mole fract acc 2% of desired for each component O2 mole fraction range 8-20%, H2 3.35 - 7.67% other gases are CO2, N2, SF6 toxic/corrosive gas (HF, SO2) cleanup required	FOMA gas bottles FOMA gas bottles FOMA gas bottles FOMA filters	intial bottle gas mixtures intial bottle gas mixtures intial bottle gas mixtures		" " " "
Post burn analysis	looking for: H2,O2,CO2,H2O, SF6, N2 & CO to 2%	Gas Chromo. Gas Chromo.			" "
Acceleration Environment	need levels 10-4 g/go needs long (~500 sec) micro-g			ARIS ISS planning	" "
Test Chamber	interior wall emmissitivity >.9 over visable initial press 1-3 atm, accuracy 3% of reading	Test chamber "			" "
Minimum # Test Pts	30 pts	CIR ops	Sofball Ops	ISS Crew time/downlk	"
Test Duration Estimate	100-500 sec	Test chamber			"
Color camera	30 fps 30 x 22.5 fov 30 cm dof 2200 um resolution	Color Cam " "			comply " "
LLL cameras -IR(2)	30 fps 30 x 22.5 fov 30 cm dof 800 nm long pass filter for 1 Cam orthogonal view to color camera	near IR LLL pkge " " " "	filter CIA arrangement		comply " " " "
LLL camera -UV	30 fps 30 x 22.5 fov 30 cm dof wavelength: 310 nm	LLL-UV pkge " " •"			" " CIR lens dof limit comply

Summary: SofBall interface requirements with CIR are capable of being met by the CIR design.



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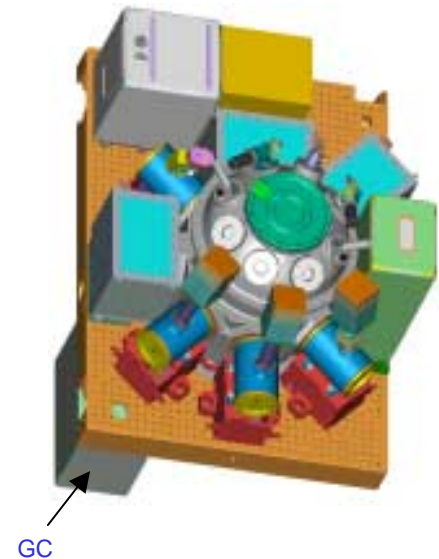
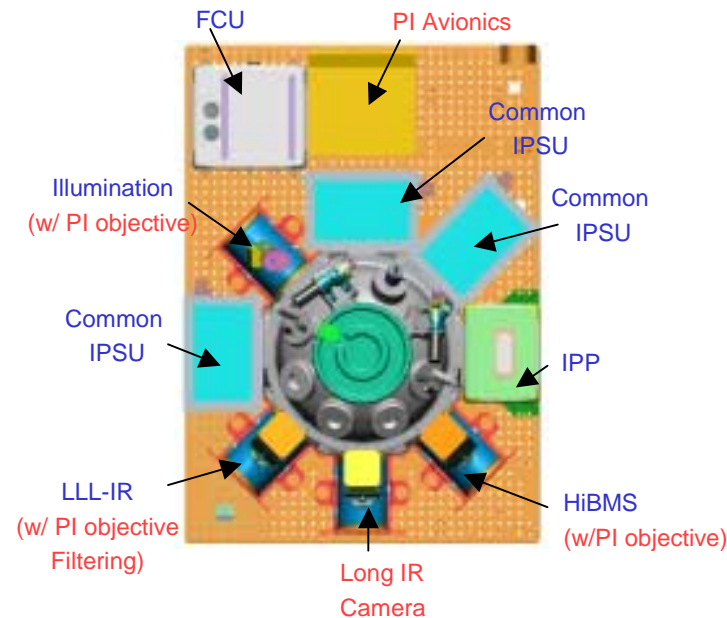
Spread Across Liquids (c3)

Real Experiment Science Summary

- PI: Dr. Howard Ross, GRC
- PS: Jack Salzman, GRC
- Being Flown in a Sounding Rocket

Experiment Summary

- Liquid Fuel fills a rectangular channel and is ignited at one end.
- Flame images, liquid- and gas-phase velocity measurements and flow visualization are acquired.



Diagnostics Layout in CIR

Key CIR - Experiment Interface Requirements

- Chamber insert would provide fuel tray and liquid fuel filling mechanism.
- Tests are usually conducted with air flow across the fuel surface.
- Diagnostics provided by CIR:
 - High Bit-depth Multi-spectral camera.
 - Low Light Level Infra-Red camera
- Acceleration environment range $< 5 \times 10^{-4}$ g/go provided by ARIS



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Summary CIR/SAL Compliance With SAL SRD/Derived Requirements

System	Key Requirement	CIR H/W	SAL H/W	Other	Compliance
Test Section Dimension	30cm length x 2.5cm height x 2 or 8 cm width	Chamber	Chamber insert		comply
Fuels & fuel condition	Butanol, Propanol, Ethanol, Methanol, Decane 60 - 600 cc of fuel required		SAL Fuel bottles		May not comply
Gas flow across fuel	5 cm/s - 30 cm/s +/- 10% Initial pressure 1 atm	FOMA System	SAL Flow tunnel		comply "
Acceleration Environment	need levels 5×10^{-4} g need freq measurement 0-10 Hz			ARIS SAMS FF	" "
Minimum # Test Pts	TBD	CIR ops	Cool Flames Ops	ISS Crew time/downlk	"
Test Duration Estimate	< 60 sec.	Test chamber			"
2 Visible Imaging	30 fps 30 cm x 5 cm fov	Color Camera & LLL-IR	LLL-IR camera objective		" "
IR Imaging	30 fps 30 cm x 7.5 cm fov		Long IR Camera		"
Temp. Field Measurement	Rainbow Schlieren: 30 fps 0.2mm resol; 10cm dia. FOV	Illumination + HiBMs	Objectives		"May not comply

Summary: There are safety concerns with using the quantities of liquid fuels required. Also accommodating PIV measurements and Rainbow Schlieren are a challenge.



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Flammability Diagrams of Combustible Material (c4)

Real Experiment Science Summary

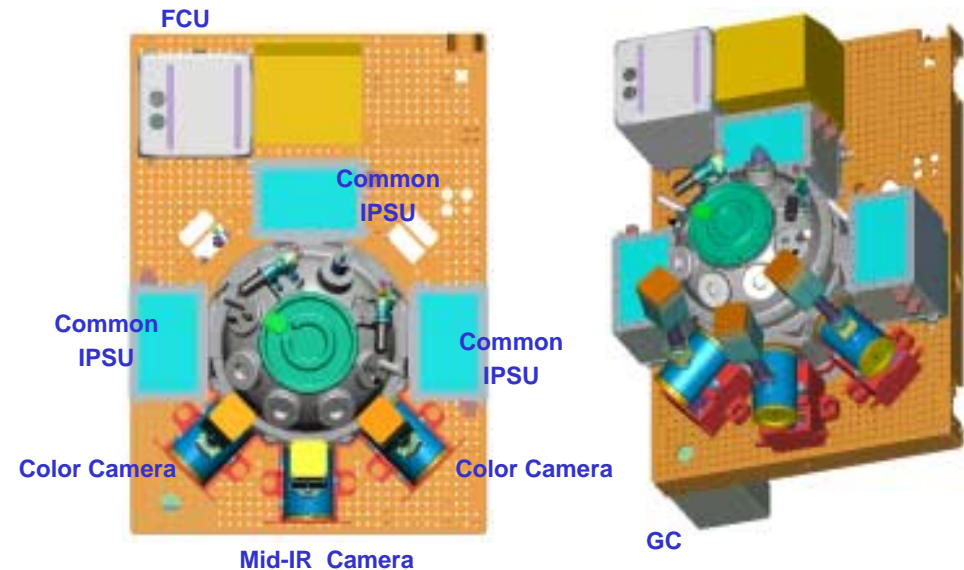
- PI Fernandez-Pello, UC Berkeley
- PS Ross GRC

Experiment Summary

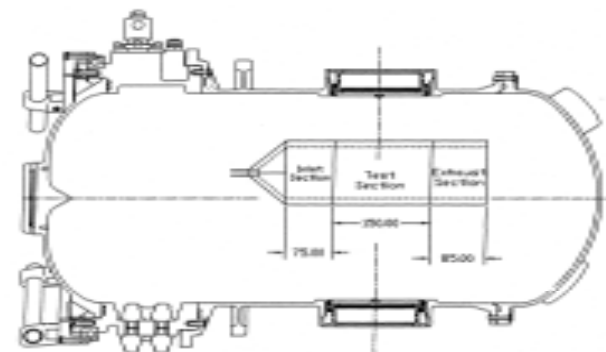
- Study ignition and flame spread of solid samples with external radiant heat flux and opposed gas flow
- Ignition time, flame spread, flame size measurements as a function of external radiant flux, flow velocity and oxygen concentration

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, igniter assembly, radiant heater and flow duct
- Operating pressure is 1 atm with O₂/N₂ mixtures provided by the FOMA. O₂ concentration range from 18 to 25%. Recirculation mechanism is PI provided
- Diagnostics provided by CIR:
 - Color images of flame spread
 - Infrared Image of fuel surface
- Acceleration environment 5x10⁻⁵ g/go provided by ARIS



Diagnostics Layout in CIR



CIR/FIST Chamber Insert Apparatus



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Summary of CIR/FIST Compliance With FIST SRD/Derived Requirements

System	Key Requirement	CIR H/W	FIST H/W	Other	Compliance
Test Chamber	Insert size: 39.1 cm long x 12.5 cm dia initial press 1 atm ± .2 atm	Chamber Test chamber	insert		comply "
Test Gas Conditions	O2 mole fract acc .5% O2 mole fraction range: 18- 25%, rest N2 < 10% relative humidity	FOMA system FOMA gas bottles FOMA filters	initial bottle gas mixtures initial bottle gas mixtures		May Comply On-going testing on O2 bleed-in system
Flow duct conditions	30 cm long x 10cm x 10cm 0-20 cm/sec over sample		Flow duct with fans		" "
Radiant sample heating	40 - 200 watts radiant power to surface	1KW @ 120V			comply
Acceleration Environment	need levels 5 x 10 ⁻⁵ g/go need freq measurement 0-10 Hz			ARIS SAMS FF	comply "
# Test Pts Test duration	32 pts + 16 desired ~ 200-1000 sec	CIR ops	FIST Ops	Crew time/downlk	"
Color camera (2)	30 fps 10 x 4 cm fov 5 cm dof standard video	Color Cam " " "			comply " " "
IR Imaging camera	30 fps 10 x 4 cm fov 5 cm dof resolution: 1000 um orthogonal view to color camera	Mid-IR cam " " " "			" " " " "
			CIA arrangement		"

Summary: FIST interface requirements with CIR will be met after successful bleed-in testing.



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Microgravity Smoldering Combustion Experiment (c5)

Real Experiment Science Summary

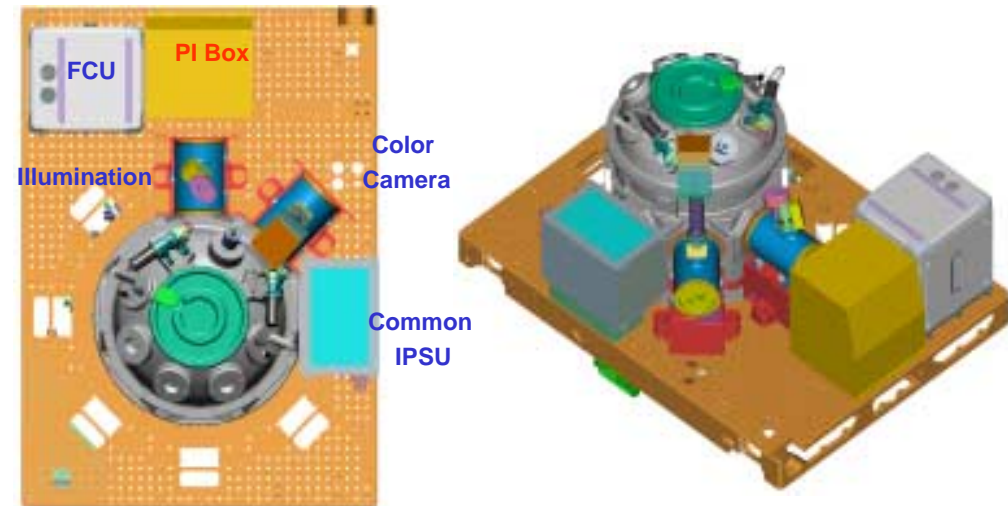
- PI: Fernandez-Pello, UC
- PS: Urban, GRC

Experiment Summary

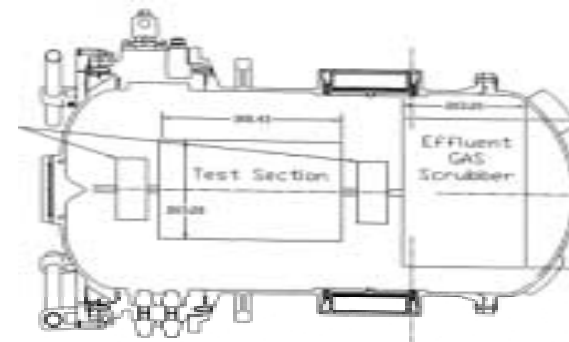
- A porous combustible sample of polyurethane foam is heated to ignition by an igniter wire under opposed or concurrent flow, or in a quiescent environment
- Smoldering combustion front is monitored and temperature measurements are taken

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, sample holder, igniter assembly, and temperature point measurement.
- Operating pressure 1 atm with O₂/N₂ mixtures ranging from 21 to 40% and oxidizer flow from 0.3 to 7 mm/s provided by the FOMA.
- Diagnostics provided by CIR:
 - Illumination of the smoldering region
 - One color image of combustion event throughout its duration.
 - Composition of O₂, CO, CO₂, N₂ and CH₄ via GC
- Acceleration environment <10⁻³ g provided by ARIS



Diagnostics Layout in CIR



CIR/MSFC Chamber Insert Apparatus



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Summary of CIR/MSC Compliance With MSC SRD/Derived Requirements

System	Key Requirement	CIR H/W	MSC H/W	Other	Compliance
Test Chamber	Insert size: 59.5 cm long x 38.1 cm dia 1atm + 10%initial pressure	Chamber Chamber	insert		comply "
Test Gas Conditions	O2 mole fraction .5% of desired relative humidity <10% O2 levels to 21-40 % He levels to 40%, rest N2	FOMA/ gas bottles FOMA filter FOMA/ gas bottles FOMA/ gas bottles	initial bottle gas mixtures initial bottle gas mixtures initial bottle gas mixtures		" " " "
Post burn analysis	looking for: CH4,CO,CO2,O2,H2O, & N2	Gas Chromo.			comply
Ultrasound imaging	5 locations in sample every 10 sec		ultrasound system		acoustic signature limits for rack
Oxidizer flow	.2 - 4.7 std liters/min	FOMA			flows below CIR FOMA limit
Acceleration Environment	need levels ~10-3 g/go			ARIS	comply
# Test Pts	12 pts	CIR ops	MSC	ISS Crew time/downlk	"
Test Duration	50-120 minutes				"
Color camera	.2 fps 12 x 10 cm fov resolution:~5000 um	Color Camera " "			" " "

Summary: MSC interface requirements with CIR are capable of being met by the CIR design.



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Laminar Soot Processes Experiment (c7)

Real Experiment Science Summary

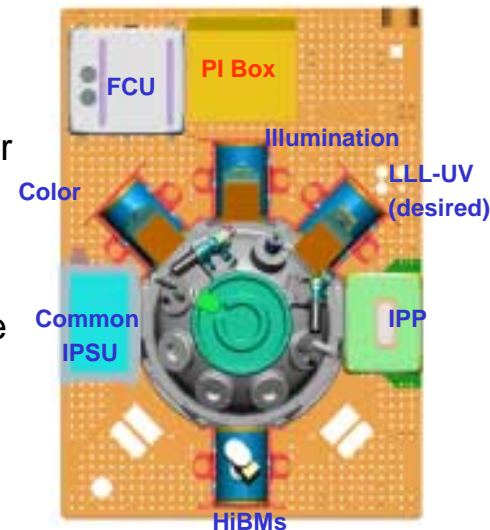
- PI: Faeth, U of Mich
- PS: Urban, GRC

Experiment Summary

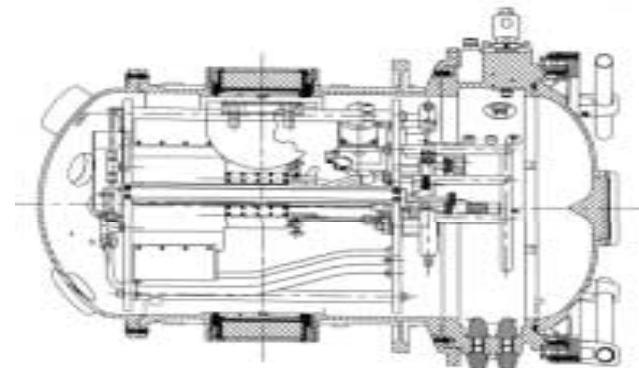
- A round laminar gas jet diffusion flame of ethylene or propane burns in an initially quiescent environment
- Soot volume fraction, soot temperature, flame radiation are measured. Soot samples are taken
- Flame shape and size, soot morphology, and smoke heights are found

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, igniter assembly, temperature point measurement and flame radiation devices and soot sampler.
- Operating pressures are 0.5 and 1 atm with O₂/N₂ mixtures provided by the FOMA. O₂ concentration 21%.
- Diagnostics provided by CIR:
 - Two orthogonal views of the flame: One color, another LLL is available for a second desired view.
 - Light absorption and 2-wavelength pyrometry images for soot volume fraction and soot temperature measurements
- Acceleration environment 10-4 g/go provided by ARIS



Diagnostics Layout in CIR



CIR/LSP Chamber Insert Apparatus



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Summary of CIR/LSP Compliance With LSP SRD/Derived Requirements

System	Key Requirement	CIR H/W	LSP H/W	Other	Compliance
Test Chamber	Insert size: 66.6 cm long x 39.6 cm dia interior wall emissivity >.8 over visible initial press .5&1 atm.final< 5%rise	Chamber Test chamber "	insert		comply " "
Test Gas Conditions	O2 mole fract acc 1% of desired O2 mole fraction 21% N2 mole fraction 78% max of 10% O2 consumed in test	FOMA gas bottles FOMA gas bottles FOMAgas bottles Gas Chromo.	intial bottle gas mixtures intial bottle gas mixtures intial bottle gas mixtures		" " " "
gaseous fuel flow	flow rate .7 - 1.93 mg/s	FOMA supply	inert nozzle		"
Soot sampling probes	TEM grids at 4 locations transit time <50 msec residence time 200-500 sec	air for insert solenoids	grids, probes solenoids "		chamber internal tap for air comply "
Acceleration Environment	need levels <10-3 g/ go need freq measurement 0-15 Hz			ARIS SAMS FF	" "
Minimum # Test Pts Test Duration Estimate	14 pts < 250 sec	CIR ops Test chamber	LSP Ops	ISS Crew time/downlk	" "
Color camera for flame imaging	1 fps 8 x 6 cm fov 2.5 cm dof resolution 750 um	Color Cam " " "			" " " "
soot volume fraction camera	wavelength: 600-900 um (675 um) resolution: 1000 nm 3 cm fov full field	HiBMs w/ filter " "			" " "
2 wavelength pyrometry	632.8 & 900 nm resolution 500um 3 cm fov full field range: 800 to 1100 K	HiBMs w/ liquid filter " " "			" " " "

Summary: LSP interface requirements with CIR are capable of being met by the CIR design.



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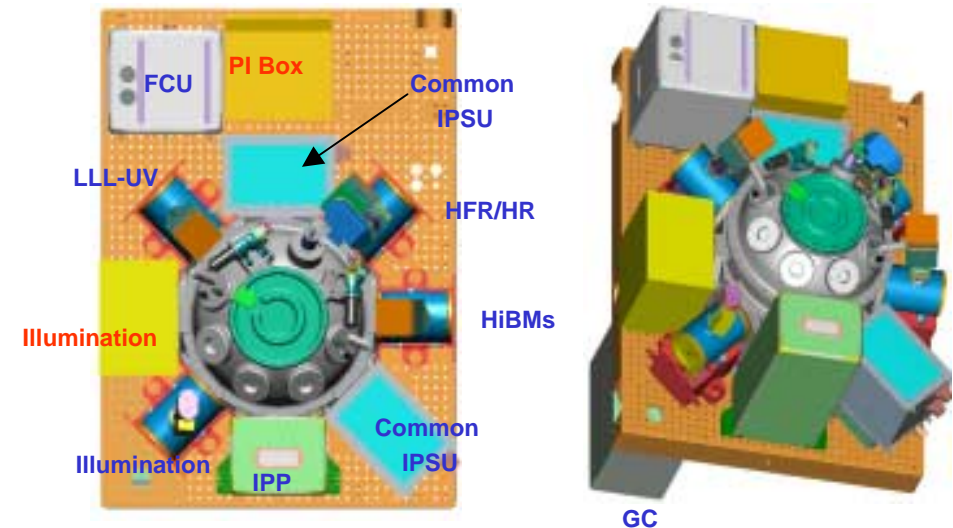
Sooting & Radiative Effects In Droplet Combustion (c8)

Real Experiment Science Summary

- PI: Choi, Drexel University
- PS: Ferkul NCMR @ GRC

Experiment Summary

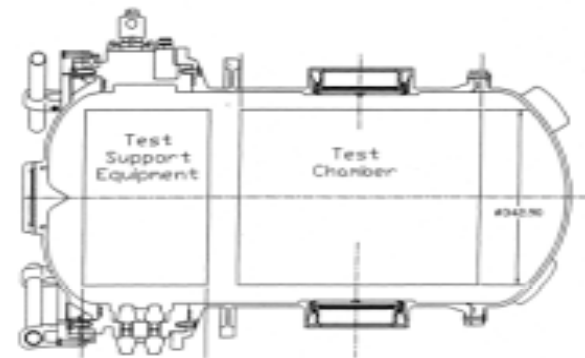
- single liquid heptane or methanol droplets burn in quiescent O₂/N₂/He environments, freely deployed and with fiber support
- droplet size, flame location, soot concentration, temperature distributions, and soot morphology are measured
- burning rate constants, flame to droplet diameter ratios, soot properties and flame extinction will be obtained



Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, igniter assembly, droplet growth and deployment system and soot sampling
- Atmosphere is .25 to 2 atm with O₂/N₂ & O₂/He mixtures provided by the FOMA. O₂ concentration range from 15 to 50%. Cleanup is between test points as necessary and before venting
- Diagnostics provided by CIR:
 - Back lit droplet images at high frame rate and high resolution
 - Soot Volume Fraction and 2-wavelength pyrometry images
 - OH flame emission images
- Color images of droplet operations and ignition provided by MDCA
- Acceleration environment 10-6 g/go provided by ARIS

Diagnostics Layout in CIR



CIR/SEDC Chamber Insert Apparatus



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Summary of CIR/SEDC Compliance With SEDC SRD/Derived Requirements

System	Key Requirement	CIR H/W	SEDC H/W	Other	Compliance
Test Chamber	Insert size: 64 cm long x 34.5 cm dia	Chamber	insert		comply
	18 to 27 oC test environment .5 to 2 atm initial pressure	Chamber Chamber		Water loop; Air cooling	" "
Test Gas Conditions	O2 mole fraction 1% of desired O2 levels to 50 %	FOMA/ gas bottles	initial bottle gas mixtures		"
		FOMA/ gas bottles	initial bottle gas mixtures		"
Acceleration Environment	need levels ~10-5 g			ARIS	"
	need measurement accuracy 10-6 g			SAMS FF	"
Droplet Imager	80 fps	HFR/HR			"
	20 um resolution @ 10x10mm IFOV	"			"
Color imager of flame	60 um resolution @ 30x30mm IFOV	HFR/HR w/o tracking			"
	>= 30 fps		Color Camera		"
OH flame imager	-				
	310+ 5 nm acceptance	LLL w/ OH Filter			comply
	30 fps	"			"
	50 um resolution	"			"
	5 cm diam. fov	"			"
2 wavelength pyrometry & soot volume fraction camera	700 & 800 nm/ 675 nm	HiBMs w/ liquid filter			currently 100ms needed for filter cycling approx. 5fps can be supported depending on exposure. 30 fps available at each wavelength
	30 fps	"			:
	resolution 50 um	"			"
	5 cm diam. fov	"			"
	range: 1000 to 2500 K, acc 50 K	"			"
	> 250 gray scales	"			"

Summary: SEDC interface requirements with CIR are capable of being met by the CIR design.



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Cool Flames (c9)

Real Experiment Science Summary

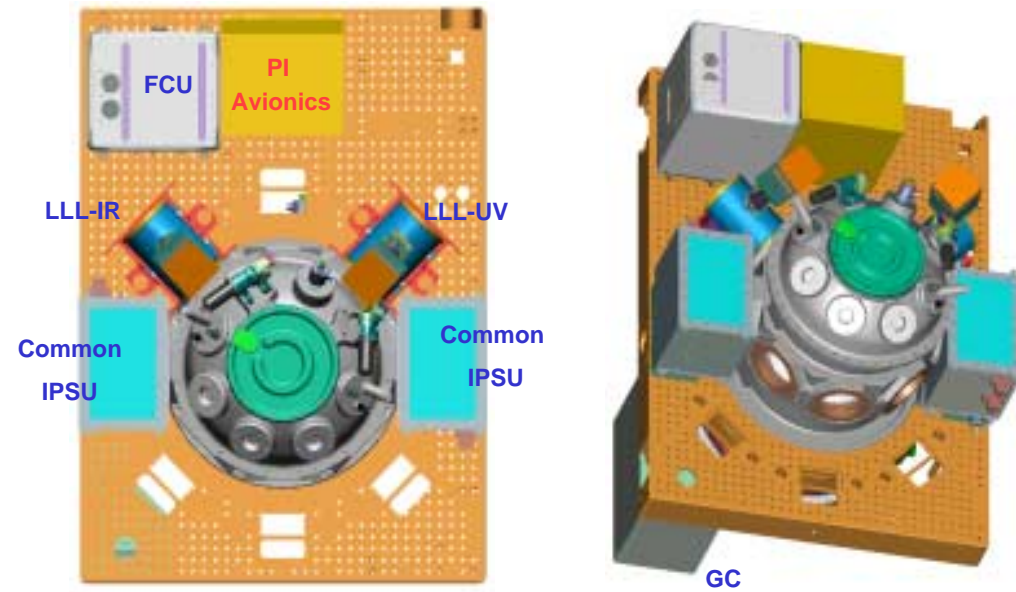
- PI: Prof. Howard Pearlman, USC
- PS: Dr. Ming-Shin Wu, NCMR
- Currently in Phase B

Experiment Summary

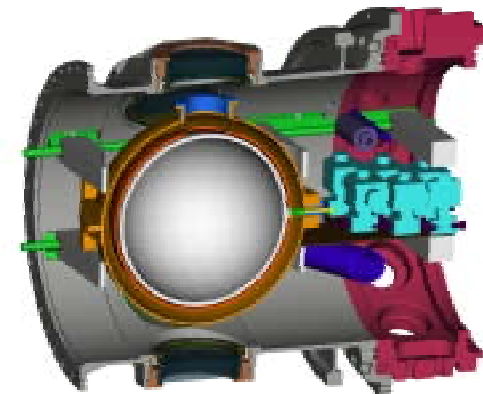
- Premixed gases are introduced to a heated (200-6000C) quartz vessel
- Reaction is observed through windows in the containment vessel which jackets the quartz vessel.

Key CIR - Experiment Interface Requirements

- Chamber insert provides quartz vessel, fluid system interfaces to CIR, temperature and pressure point measurement devices.
- CIR chamber will be evacuated prior to and during the experiment operations.
- Diagnostics provided by CIR:
 - Low Light Level Ultra-Violet camera.
 - Low Light Level Infra-Red camera
- Acceleration environment range $< 3 \times 10^{-5}$ g/go provided by ARIS



Diagnostics Layout in CIR



CIR/Cool Flames Chamber Insert Apparatus



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Summary CIR/Cool Flames Compliance With Cool Flames SRD/Derived Requirements

System	Key Requirement	CIR H/W	Cool Flames H/W	Other	Compliance
Test Chamber	Vessel size \geq 20 cm. Internal dia. Initial vessel Temp 200-600°C	Chamber	Vessel & Vessel heater		comply "
Test Gas Conditions	Mixtures of 50%propane/50% O ₂ required Mixtures of H ₂ & O ₂ desired Required inerts He, Ar, Kr Uniformity \pm 0.1% by volume Accuracy is \pm 0.5% by volume	FOMA gas bottles FOMA gas bottles	intial bottle gas mixtures intial bottle gas mixtures		May not comply Comply " " "
Operating Pressure	100 to 1300 Torr Initial pressure 10 mTorr or below	Vacuum Exhaust			" "
Acceleration Environment	need levels 3×10^{-5} g need freq measurement 0-50 Hz			ARIS SAMS FF	" "
Minimum # Test Pts	50 pts	CIR ops	Cool Flames Ops	ISS Crew time/downlk	"
Test Duration Estimate	Minutes up to 2 hrs.	Test chamber			"
Low light level imaging	30 fps & 100 fps 20 cm dia. fov 3 cm dof Spatial resolution: \geq 2 pixels/mm	LLL-UV & IR " " "			100 fps impacts 10% of test matrix Comply "
Chemical Composition	Desired Species: C ₃ H ₈ , O ₂ , CO, CO ₂ , C ₂ H ₄ , CH ₃ CHO, CH ₃ OH, C ₃ H ₆ , C ₃ H ₆ O, C ₂ H ₅ CO, H ₂ , H ₂ O, H ₂ O ₂	Gas Chromatograph " " " •"	Sample Probes		Issues with sampling and Measuring some of these species

Summary: There are safety concerns with using the premixed gasses with the FOMA system that need to be resolved. A different camera may be used to accommodate the 100 fps requirement.



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Solid Inflammability Boundary At Low Speed (c10)

Real Experiment Science Summary

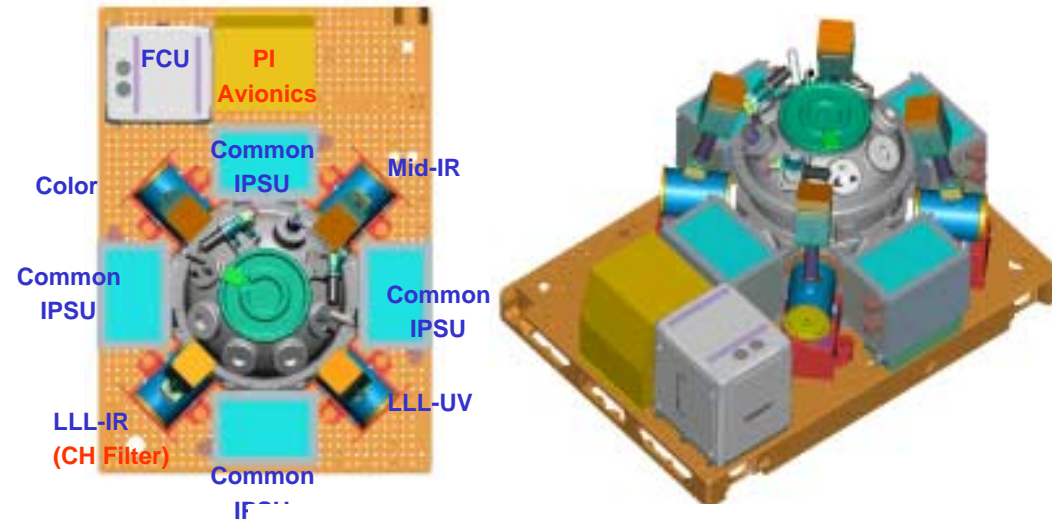
- PI: T'ien, Case-Western
- PS Ferkul, NCMR @ GRC

Experiment Summary

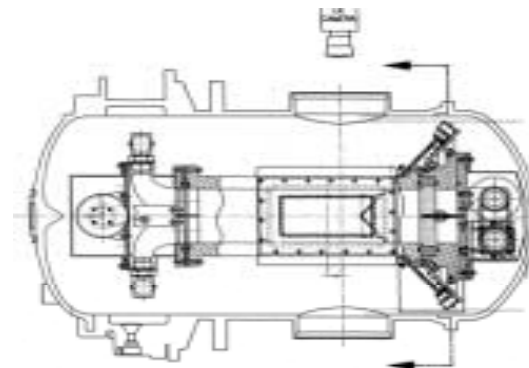
- Verify predicted extinction boundaries in concurrent flame spread across a thin solid fuel.
- Flame spread, flame size and shape, temperature, heat release measurements are made at a series of gas flow velocities and oxygen concentrations.

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, igniter assembly, temperature point and radiometric measurement devices
- Operating pressure is 1 atm with O₂/N₂ mixtures provided by the FOMA. O₂ concentration between 10% and 30%.
- Diagnostics provided by CIR:
 - One color, one CH and one OH view of the flame.
 - Infrared imaging of CO₂, H₂O and soot fields
 - Chemical composition of the burned gas samples
- Oxidizer flow from 0 to 15cm/s can be partially provided by FOMA
- Acceleration environment range 10-4 g/go provided by ARIS



Diagnostics Layout in CIR



CIR/SIBAL Chamber Insert Apparatus



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Summary of CIR/SIBAL Compliance With SIBAL SRD/Derived Requirements

System	Key Requirement	CIR H/W	SIBAL H/W	Other	Compliance
Test Chamber	Insert size: 78.3 cm long x 38.1 cm dia initial press 1 atm .05 atm	Chamber Test chamber	insert		comply
Test Gas Conditions	O2 mole fract acc 1% O2 mole fraction range: 10- 30%, rest N2 < 50% relative humidity	FOMA system FOMA gas bottles FOMA filters	initial bottle gas mixtures		comply " "
Flow duct conditions	30 cm long x 10cm x 10cm	Chamber re- circulation to ignition	Flow duct w/fans		May Comply-On going bleed in method being tested
Acceleration Environment	need levels 5 x 10-5 g/go need freq measurement 0-10 Hz			ARIS SAMS FF	comply "
Minimum # Test Pts	60 pts	CIR ops	SIBAL Ops	Crew time/downk	"
Test duration	300 seconds				CIR FOMA supply flow time
Flame imaging	30 fps 10 x 10 cm fov resolution: 200 um	Color Camera " "			comply " "
CH flame zone edge image	wavelength 431 nm (CH) >10 fps 10 x 10 cm fov resolution: 200 um	LLL-IR " " "	CH filter		" " " "
IR flame zone & fuel surface measurement camera	Flame wavelengths:4.3(CO2),1.87(H2O),1.6,&3.8um >1 fps 10 x 10 cm fov resolution: 200 um	Mid-IR pkge " " "	multielement filter wheel & insert mirror assembly		comply camera sensitivity @1.6 & 1.87um must be tested " "
OH flame imager	wavelength 310 nm (OH) >1 fps 10 x 10 cm fov resolution: 200 um	LLL-UV w/OH filter " " "			comply " " "

Summary: SIBAL interface requirements with CIR will be met after successful bleed-in testing.



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Transition From Ignition to Growth Under External Radiation (c11)

Real Experiment Science Summary

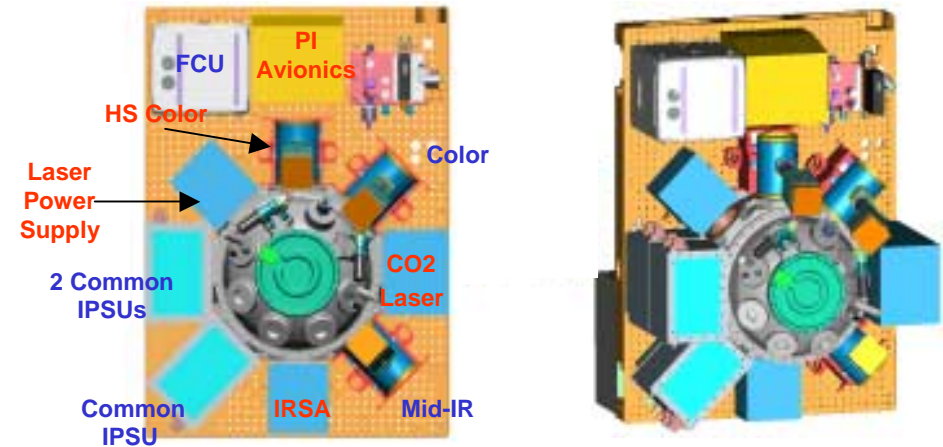
- PI: Kashiwagi, NIST
- PS: Olson, GRC

Experiment Summary

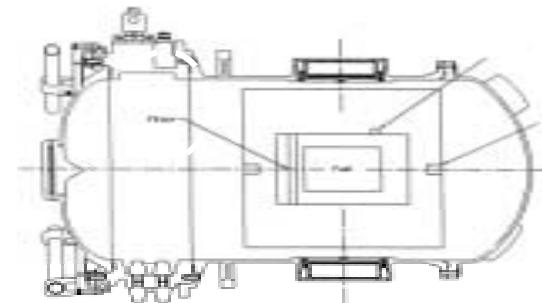
- Study 2 and 3 dimensional radiant ignition and transition to flame spread of solid cellulose and PMMA samples under low speed flows.
- Ignition time, shape and flame size, flame color, spectral emissions and temperature measurements are made.

Key CIR - Experiment Interface Requirements

- Chamber insert provides fuel, temperature point measurement devices and fans for oxidizer flow. CO₂ ignition system external to chamber.
- Operating pressure is 1 atm with O₂/N₂ mixtures provided by the FOMA. O₂ concentration 21%.
- Diagnostics provided by PI: High speed color sample edge view and IRSA system
- Diagnostics provided by CIR:
 - Two color images: one edge view and one surface view.
 - IR images of fuel surface temperature
 - Chemical composition of the burned gas samples
- Acceleration environment range 10-4 g/go provided by ARIS



Diagnostics Layout in CIR



CIR/TIGER-3D Chamber Insert Apparatus



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Summary of CIR/TIGER 3-D Compliance With TIGER 3-D SRD/Derived Requirements

System	Key Requirement	CIR H/W	TIGER 3D H/W	Other	Compliance
Test Chamber	Insert size: 40 cm long x 40 cm dia initial press 1 atm, 0.05 atm	Chamber Test chamber	insert		comply "
Test Gas Conditions	O2 mole fract acc .3% O2 mole fraction range: 20.9%, res N2	FOMA system FOMA gas bottles	initial bottle gas mixtures initial bottle gas mixtures		" "
Flow duct conditions	24 cm long x 14cm x 14cm 0-15 cm/sec flow through		Recirculation fan in chamber O2 sensor		May Comply O2 bleed in method testing on-going
Acceleration Environment	need levels 10-4 g/go need freq measurement 0-10 Hz			ARIS SAMS FF	comply "
Minimum # Test Pts Test duration	30 pts ~ 20 minutes	CIR ops	Tiger 3D ops	Crewtime/down k	" CIR FOMA supply flow time
Laser Ignition in 2-d & 3 -d tests	Up to 1600 Watts		CO2 laser, turning mirrors, focusing optics & windows		May comply Using 120V supply + Water Cooling
Color camera surface view	30 fps 10 x 10 cm fov resolution: 500 um	Color Camera " "			comply " "
Color camera edge view	30 fps 4x 3 cm fov resolution: 250 um		Color Camera (IRSA)		" " "
Color camera (edge view)	200-500 fps 4x 3 cm fov resolution: 250 um		high speed color camera		comply " "
IR Imaging camera for surface temperature	60 fps 8 x 10 cm fov resolution: 500 um temperature range: 400 -1100K	Mid-IR pkge & windows " "			" " " "

Summary: TIGER -3D requirements will be met with CIR/FCF resources.



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Combustion Experiments – Utilization of FCF Provided Hardware

EXP HARDWARE	1	2	3	4	5	6	7	8	9	10	11	% Utilization
HFR/HR						1		1				18%
HiBMS							1	1				18%
Color Camera	1	1		1	1		1			1	1	64%
LLL-UV	1	1				1	1	1	1	1		64%
LLL-IR		1							1	1		27%
Mid-IR				1						1	1	27%
Illumination					1	1	1	1				36%
Common IPSU 1	1	1		1	1	1	1	1	1	1	1	91%
Common IPSU 2	1	1		1		1	1	1	1	1	1	82%
Common IPSU 3		1		1		1				1	1	45%
IPP						1	1	1				27%
FCU	1	1	1	1	1	1	1	1	1	1	1	100%
GC	1	1	1	1	1	1	1	1	1	1	1	100%
SAMS Head	1	1	1	1	1	1	1	1	1	1	1	100%
Vent/Vacuum	1	1	1	1	1	1	1	1	1	1	1	100%
Water	1	1	1	1	1	1	1	1	1	1	1	100%
GN2	1	1	1	1	1	1	1	1	1	1	1	100%
ATCU	1	1	1	1	1	1	1	1	1	1	1	100%
ARIS	1	1	1	1	1	1	1	1	1	1	1	100%
Fire Suppression	1	1	1	1	1	1	1	1	1	1	1	100%



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Combustion Experiments – Utilization of PI Provided Hardware

EXPERIMENT HARDWARE	1	2	3	4	5	6	7	8	9	10	11	% Utilization
Color Camera #1						1		1				18%
Color Camera #2				1								9%
High Speed Color											1	9%
LLL-IR		1										9%
Illumination								1				9%
Common IPSU 4										1		9%
Long IR Camera			1									9%
Radiometer (CIA)	1	1	1	1	1	1	1	1	1	1	1	100%
Radiant Heater #1				1								9%
Radiant Heater #2											1	9%
Chamber Insert Assy	1	1	1	1	1	1	1	1	1	1	1	100%



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Summary Compliance Summary for Combustion Basis Experiments and Real Experiments

BASIS EXPERIMENTS	1	2	3	4	5	6	7	8	9	10	11
Comply											
Hardware											
Bench Volume											
Data [GB]	243.3	144	4.89		6.7		2.96				
Mass (Base)	943 kg	995 kg	966 kg		946 kg		1001 kg				
Power (Peak/Ave)	1.5 kW/ 744W	2.1 kW/ 742W	2.1 kW/ 742 kW		1.6 kW / 840W		1.7 kW / 710 W				
Energy [kW-h]	286	156	33.5		77		90				

REAL EXPERIMENTS				FIST		DGE-II		SEDC	Cool Flames	SIBAL	TIGER-3D
Accommodate											
Hardware											
Bench Volume											
Data [GB]				481		1355		153	3517	687	2228.5
Mass (Base)				977 kg		1021 kg		1021 kg	949 kg	958 kg	984 kg
Power (Peak/Ave)				2.4 kW/ 667 kW		2.1KW/ 698W		2.1 kW/ 819 W	1.6 kW/ 569W	2.4 kW/ 692 W	3.7 kW/ 670W
Energy [kW-h]				242		477		161	1008	408	727

Comply

Caution